AD-A102 387 AIR FORCE HUMAN RESOURCES LAB BROOKS AFB TX F/G 14/1
LIFE CYCLE COSTING OF SIMULATED VERSUS ACTUAL EQUIPMENT FOR INT--ETC(U)
JUL 81 F T EGGEMEIER, G A KLEIN
UNCLASSIFIED AFHRL-TP-81-16 NL

1 OF 1
AD A
102387

END
DATE
FILMED
8-81
DTIC

AFHRL-TP-81-16

LEVEL II

(12)

AIR FORCE

HUMAN RESOURCES

LABORATORY

LIFE CYCLE COSTING OF SIMULATED VS ACTUAL EQUIPMENT FOR INTERMEDIATE MAINTENANCE TRAINING

By

F. Thomas Eggemeier
Gary A. Klein

LOGISTICS AND TECHNICAL TRAINING DIVISION
Wright-Patterson Air Force Base, Ohio 45433

July 1981

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

This paper has been reviewed and is approved for publication.

ROSS L. MORGAN, Technical Director
Logistics and Technical Training Division

DONALD C. TETMEYER, Colonel, USAF
Chief, Logistics and Technical Training Division

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFHRL-TP-81-16
2. GOVT ACCESSION NO.: AD-A102 387
3. RECIPIENT'S CATALOG NUMBER:
4. TITLE (and Subtitle): LIFE CYCLE COSTING OF SIMULATED VS ACTUAL EQUIPMENT FOR INTERMEDIATE MAINTENANCE TRAINING
5. TYPE OF REPORT & PERIOD COVERED: Interim
6. PERFORMING ORG. REPORT NUMBER:
7. AUTHOR(s): F. Thomas Eggemeier, Gary A. Klein
8. CONTRACT OR GRANT NUMBER(s):
9. PERFORMING ORGANIZATION NAME AND ADDRESS: Logistics and Technical Training Division, Air Force Human Resources Laboratory, Wright-Patterson Air Force Base, Ohio 45433
10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62205F 17100340
11. CONTROLLING OFFICE NAME AND ADDRESS: HQ Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235
12. REPORT DATE: July 1981
13. NUMBER OF PAGES: 20
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):
15. SECURITY CLASS. (of this report): Unclassified
15a. DECLASSIFICATION DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

This paper was presented at the 22nd Annual Meeting, 1978, of the Human Factors Society.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

life cycle costing
maintenance training
simulators
training costs
training equipment

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Life cycle cost estimates of training equipment for F-16 Avionics Intermediate Station personnel were developed. The major purpose was to compare the cost of intermediate level maintenance training when conducted on simulated vs actual avionics test equipment. This was the initial phase of a planned two-part effort. The analysis was therefore limited to estimates of training device acquisition and maintenance costs. Total estimated fifteen year costs for simulated equipment trainers were approximately 50% less than comparable estimates for actual equipment trainers.

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

AFHRL Technical Paper 81-16

July 1981

LIFE CYCLE COSTING OF SIMULATED VS ACTUAL EQUIPMENT FOR INTERMEDIATE MAINTENANCE TRAINING

By

F. Thomas Eggemeier
Gary A. Klein

Paper presented at the 22nd Annual Meeting, 1978, of the Human Factors Society

This publication is primarily a working paper.
It is published solely to document work performed.

A

LIFE CYCLE COSTING OF SIMULATED VS ACTUAL EQUIPMENT FOR INTERMEDIATE MAINTENANCE TRAINING

F. Thomas Eggemeier and Gary A. Klein

Logistics and Technical Training Division
Air Force Human Resources Laboratory
Wright-Patterson Air Force Base Ohio 45433

Life cycle cost estimates of training equipment for F-16 Avionics Intermediate Station personnel were developed. The major purpose was to compare the cost of intermediate level maintenance training when conducted on simulated vs actual avionics test equipment. This was the initial phase of a planned two-part effort. The analysis was therefore limited to estimates of training device acquisition and maintenance costs. Total estimated fifteen-year costs for simulated equipment trainers were approximately 50% less than comparable estimates for actual equipment trainers.

INTRODUCTION

This paper reports the initial results of a two-phase effort to develop life cycle cost (LCC) estimates of training equipment for F-16 Avionics Intermediate Station (AIS) maintenance personnel. The goal of the entire effort is to estimate the LCC of simulated test equipment versus actual test equipment in training personnel to operate and maintain the F-16 AIS. This initial phase was a preliminary analysis of major cost factors differentiating simulated and actual test equipment. It was conducted to provide an early estimate of the cost of a training simulator and also to decide if a more detailed LCC study was warranted.

The AIS is the set of maintenance equipment required to test aircraft avionics units which have malfunctioned on the aircraft and have therefore been removed. The AIS is used to identify the specific fault in the unit so that the operator can remove and replace the subcomponent responsible for the malfunction. The operator is responsible for using the AIS to test, troubleshoot, and perform maintenance actions on units. Maintainer personnel, on the other hand, are responsible for maintaining and repairing the AIS itself. In this context, the AIS itself constitutes one training device which could be used to support the training of operators and maintainer personnel, and a simulated AIS would constitute an alternative training device.

Simulators have a number of potential advantages over actual equipment in maintenance training, primarily in the areas of cost, safety, and reliability (Miller & Rockway, 1975; Modrick, Kanarick, Daniels, & Gardner, 1975). For example, since actual equipment trainers normally operate with high voltages, instructors are often reluctant to allow students to perform hands-on training, fearing injury to the student or damage to the equipment. Consequently, the effectiveness of the trainer is compromised. Several other factors contribute to the potential for increased effectiveness of simulators relative to actual equipment. These include the ability of the simulator to train the repair of a broader range of malfunctions, permit greater environmental control, and provide a wider variety of instructional actions and conditions. Ease of device modification and greater reliability are also potential advantages of simulation over actual equipment. These potential

advantages make simulation an alternative worthy of serious consideration when acquiring training equipment.

On the other hand, the use of actual AIS equipment for training has some potential advantages when compared to a simulated equipment trainer. The actual equipment is more realistic, thereby potentially promoting greater user acceptance. It is readily available as an add-on procurement. Simulators require special procurements, the development of new hardware and software, and the introduction of new maintenance requirements into the supply system.

Among the potential differences between simulators and actual equipment, cost is obviously of major importance in deciding which type of training equipment to procure. This paper addresses the cost aspect of choice of a training device.

METHOD

Cost Model

Cost factors for the analysis were selected from a training cost model developed by Braby, Henry, Parrish, and Swope (1975). The model includes the provision for costing a variety of training program factors. The model includes six major areas: facilities, equipment, instructional material, personnel, supplies, and students.

The Braby *et al*. (1975) model has been previously used to estimate costs of intermediate maintenance simulators (Daniels & Cronin, 1975; Daniels, 1976). Both previous efforts demonstrated a significant potential for cost savings with use of simulated equipment. Both studies also indicated that

equipment costs and school personnel costs were the two major areas which were significantly affected by use of simulators rather than actual equipment. In both studies, these two categories accounted for over 95% of the estimated LCC savings with use of simulated equipment. Of the two factors, equipment costs represented the most significant element differentiating actual from simulated equipment and accounted for more than 60% of the estimated savings.

Since equipment costs represent the majority of estimated savings attributed to simulation in previous analyses, it was decided that this preliminary estimate would be conducted with primary focus on equipment costs. Emphasis in this effort was therefore placed on the cost factor with the greatest potential to show a clear differentiation between simulation and actual equipment trainers.

Procedure

A design team, consisting of training psychologists and a simulation engineer, was assembled to perform the analysis. To meet the objective of comparing simulated and actual equipment costs, the design team applied a three-step process. During Step One, analyses were conducted to determine a set of training requirements for test station operators and maintainers. Step Two consisted of developing a conceptual design for a representative AIS simulation that would satisfy those training requirements. During Step Three, acquisition and maintenance costs were derived for the training simulator and for an actual equipment trainer.

Derivation of Training Requirements

Operator Training Requirements. Training requirements should, ideally, be derived from a complete Instructional Systems Development (ISD) analysis. However, ISD data were not available for use during this effort. Therefore, it was necessary to identify operator training requirements primarily through an analysis of task data provided in an F-16 Task and Skill Analysis Report. This report was supplemented with information gathered through interviews with F-16 personnel and F-15 AIS instructor and maintenance personnel. A technique of analyzing analogous training situations to derive the training requirements of new systems (Cream, Eggemeier, & Klein, 1978) was used in this effort. Choice of the F-15 AIS was based on the fact that it was the closest existing analog to the planned F-16 AIS.

An F-16 AIS consists of four test stations. Each station is automatic, in that its software is capable of performing the majority of necessary tests without operator intervention, once the aircraft avionics unit has been connected to the station. Avionics units are connected to the test station by means of interface test adaptors. The automatic testing procedures are designed to identify malfunctions to the subcomponent level. The subcomponent can then be removed and replaced by the operator.

The task analyses and interview data indicated that in general, the primary functions of the F-16 AIS operator are to set up the test station, perform the necessary procedures to test the units, remove and replace defective subcomponents, and verify proper operation of the avionics units after they had been repaired.

Task data were gathered for each avionics unit at each test station and summarized in a matrix format. From the matrix, it was possible to identify patterns of operator tasks and relate these to avionics units. The matrix was then used to determine the minimum number of units which would ensure training of each of the tasks required to operate the test station. On the basis of this procedure, twelve of thirty-four avionics units were identified as training requirements. Only the peripheral equipment and the interface test adaptors required to test these selected units were included as training requirements.

Maintainer Training Requirements. Derivation of training requirements for maintainer personnel was more complex than for the operator, due to the absence of any maintainer task data. During interviews, F-15 AIS and F-16 engineering prsonnel directly identified areas within the test station that would be expected to fail most frequently and be most difficult to repair. While this procedure was not as thorough as listing all tasks, it provided a direct assessment of the anticipated major training requirements.

It was determined that the major requirement for the station maintainer is access to the interior of the test station in order to effect repairs. Interviews pinpointed the computational and switching element within a test station as the areas of least reliability. It was therefore decided that the repair of the Computer and the Switching Unit/Measurement and Stimulus System (SUMSS) elements in the F-16 AIS should be among the primary training requirements.

Development of Simulation Requirements

The methods used to derive necessary simulation capability from training requirements have been described by Cream, Eggemeier, and Klein (1975, 1978). In the case of the operator tasks, the derivation was straightforward. A set of representative avionics units, test adaptors, and peripheral equipment had been identified as necessary to provide adequate training. The simulation requirements consisted of providing these elements of equipment and the components of the test station itself that were involved in testing avionics units.

It was determined that simulation of only front panels on each test station was required for the operator, who typically works with only the exterior portions of the station. Three representations of front panels were used: (1) actual equipment; (2) simulated panels with knobs, switches, and displays functional; and (3) mock-up via photo or other type of flat representation. In order to provide a direct LCC comparison with actual equipment, a simulator configuration which included all four test stations was developed.

Determination of simulator capabilities for maintainer personnel was also based upon the primary training requirements that had been identified. Training requirements were developed in terms of the electronic cards within the test station. The determination of simulator capabilities indicated that the trainee should be able to perform troubleshooting actions down to the level of testing cards and components of cards within the test station. Simulation of a core set of SUMSS cards and a number of computer sub-assembly

card modules was therefore necessary to provide the maintainer with troubleshooting experience on each category of card function within the station.

The frequency of use of each of the SUMSS cards was determined from the F-16 AIS Preliminary Design Review data, as was the circuit function, connection in the test station, and distribution throughout the test station. Cards were then selected so that a representative of each major functional category was included in the simulation. On the basis of that criterion, 29 cards distributed across the four test stations were chosen for simulation. The remaining 316 cards were designated for mock-up only.

Pertinent literature was assembled and analyzed to determine computer chassis access procedures, computer circuit functions, and computer card complexity. Card function was the criterion used to assess the appropriate degree of simulation for the computer. Subassembly computer card modules were chosen for simulation to represent a broad range of functions. On the basis of these criteria, ten computer card modules were chosen for some degree of simulation. Simulated operating components, simulated components, and photo or other flat representation mock-ups comprised the major simulation categories.

RESULTS

Simulator Acquisition Cost Estimate

Estimates of acquisition costs for each simulated test station were developed. Acquisition cost estimates were based on three major cost factors: (1) Design and fabrication of simulators; (2) Engineering change

proposals during the simulator development cycle; and (3) Technical Order data required to support the simulators when they had been placed in the field.

Design and fabrication costs included estimated design and software development costs, costs for fabrication of simulated test stations, and the cost of the materials required for the fabrication. Cost estimates in each case were based upon "best commercial practices." The total estimated design and fabrication cost for the simulated test stations was $3.3 million (M) dollars.

In order to estimate the costs of engineering change proposals, it was assumed that a four-year development cycle would be required to procure the simulated stations. Engineering change costs were then estimated in the following manner: 20% of the estimated design and fabrication costs for the first year of development, and 15%, 10%, and 5% of design and fabrication costs for the second, third, and fourth years of development, respectively. The total estimated engineering change cost for the simulated stations was $1.6M.

Costs associated with procurement of technical data for the simulators were estimated to be 7.25% of the estimated design and fabrication costs. Estimated technical data costs were $250 thousand (K) dollars.

The estimated total acquisition cost for the simulated stations is therefore $5.2M.

Simulator Maintenance Cost Estimate

Estimates of fifteen-year maintenance costs for the simulator were developed. It was assumed that major maintenance work on the simulator would

be contracted. The manufacturer of the computer specified to drive the simulation provided an estimate of labor for one year on the computer and associated peripherals. Although it was estimated that the remaining electronics in the simulated test station would not equal the computer in complexity to maintain, the labor estimate for the computer was doubled to arrive at a conservative one-year labor estimate for the entire simulated test station. The one-year labor estimate was inflated at 10% per year for the fifteen years of the life cycle in order to arrive at the fifteen-year estimate of maintenance labor for one simulated test station. The estimate for one station was then multiplied by four to arrive at an estimate for all four stations. Estimated fifteen-year maintenance labor costs were $432K.

In order to estimate the costs of spares for the simulation, a percentage of the total design and fabrication costs for the four simulated test stations was calculated. This percentage varied over the fifteen-year cycle, beginning with approximately 9% of design and fabrication costs per year for the first two years, and 1% of design and fabrication costs per year for the remaining thirteen years of the life cycle. It was assumed that the majority of simulator spares would consist of initial spares lay-in with minimal requirements for replenishment spares. This assumption is based on the assumed high reliability of simulators. Each year's estimates were then summed to yield the fifteen-year estimate for spares for all four stations. The estimated fifteen-year cost of spares was $722K.

The total estimate fifteen-year maintenance costs for the simulated AIS is therefore $1.15M.

Total Cost Estimate for the Simulator

A summary of the major cost elements for the simulated AIS is provided in Table 1. The total fifteen-year cost estimate is $6.35M.

TABLE 1

Summary of Major Cost Elements for the Simulated AIS	
Estimated Acquisition Cost	$5.20M
Estimated 15-Year Maintenance Cost	$1.15M
Total Estimated Simulated AIS Cost	$6.35M

Estimated Actual Equipment Costs

Data were available from Air Force training device procurement sources on the estimated costs for acquisition of all four actual test stations, a complete set of thirty-four avionics units and interface test adaptors, calibration requirements, and the costs of initial spares for two years for the test stations and associated peripheral equipment. Since the analysis of station operator functions conducted to specify simulation requirements had indicated that only twelve of the thirty-four avionics units and associated test adaptors would be required to accomplish the required training, the actual equipment costs estimates were reduced 35%. This reduction was accomplished in order to make the configuration of actual equipment as comparable as possible to that of the simulator. The adjusted total acquisition cost for the actual AIS was $7.15M.

Since the available data provided estimates for the initial two years of spares, the remaining thirteen years of spares were calculated at 1% of

acquisition costs per year. The estimated fifteen-year cost of spares for the actual AIS was $2.25M.

Data were also available from Air Force sources concerning the estimated cost of Air Force manpower required to maintain the actual AIS for fifteen years. The total estimated fifteen-year labor cost for the actual AIS was $3.3M.

The total estimated fifteen-year maintenance cost for the actual AIS is therefore $5.55M.

A summary of major cost elements for the actual AIS is provided in Table 2. The total fifteen-year cost estimate is $12.7M

TABLE 2

Summary of Major Cost Elements for the Actual AIS

Estimated Acquisition Cost	$7.15M
Estimated 15-Year Maintenance Cost	$5.55M
Total Estimated Actual AIS Cost	$12.7M

DISCUSSION

The results indicate that the procurement and maintenance of simulation offers a significant potential for cost avoidance when compared with actual equipment costs. Total estimated fifteen-year costs for simulated equipment were $6.35M, while comparable estimates for actual equipment were $12.7M, a savings of 50% with use of simulated equipment. Efforts were made to provide a direct comparison of actual and simulated equipment by considering all four test stations, specifying equal numbers of avionics units for both actual equipment and the simulation, and excluding automated instructional features

from consideration. It has been suggested (e.g., Daniels & Cronin, 1975; Daniels, 1976) that simulation permits automation of instructional functions that can permit significant savings in instructor costs, and, possibly, trainee costs. This effort did not address this potential cost impact for the reasons cited earlier.

It should be noted that this analysis addressed only the cost aspect of choice of training device. The question of the relative training effectiveness of simulation and actual equipment was beyond the scope of this effort. At the present time, there are no reports in the literature which compare the training effectiveness of simulators and actual equipment for intermediate maintenance training. Such training effectiveness data, when available, will obviously be of critical importance in choosing a training device.

Based on the present results, plans have been made to initiate the detailed LCC analysis. The detailed LCC study will assess the adequacy of the techniques used in this study, with the goal of determining how they might be refined for future efforts. Also, the detailed analysis can indicate the general level of confidence that can be expected with the methods used to develop the estimate in this report.

Since this study was undertaken at a time when the actual F-16 AIS was in a state of flux, some current estimates may require alteration, due to decisions made subsequent to the analysis period. Attempts have been made to minimize error by using the latest available data.

The potential value of this effort extends beyond determining whether or not to continue with a subsequent detailed LCC study. It demonstrates a method for deriving cost estimates based on limited data. No actual F-16 AIS stations were in existence during this work. Further, there were no simulators in existence during this work that were of this type of training device, although two such simulators were under construction. Therefore, the configuration of an appropriate simulation had to be predicted, since there were only minimal task analysis data available for the nonexistent AIS station. The requirement for LCC estimation in the absence of complete data is not atypical, and this report describes methods for providing such estimates.

REFERENCES

Braby, R., Henry, J. M., Parrish, W. F. & Swope, W. M. A Technique for Choosing Cost-Effective Instructional Delivery Systems, TAEG Report #16, Orlando, FL: Naval Training Analysis and Evaluation Group, 1975.

Cream, B. W., Eggemeier, F. T., & Klein, G. A. Behavioral Data in the Design of Aircrew Training Devices. In R. N. Hale, R. A. McKnight, & J. R. Moss (Eds.) Proceedings, Human Factors Society 19th Annual Meeting, 1975, pp. 260-266.

Cream, B. W., Eggemeier, F. T., & Klein, G. A. A Strategy for the Development of Training Devices. Human Factors, 1978, 20, 145-158.

Daniels, R. W., & Cronin, J. E. Feasibility of Automated Electronic Maintenance Training (AEMT) Volume II - Cost Analysis. NADC Report 75177-40, Warminster, PA: Naval Air Development Center, 1975.

Daniels, R. W. Draft Report, NAVTRAEQUIPCEN 75-C-0085, Orlando, FL: Naval Training Equipment Center, 1976.

Miller, G. G., & Rockway, M. R. Maintenance Training in Advanced Instructional Systems. In W. J. King and J. S. Duva (Eds.) New Concepts in Maintenance Trainers and Performance Aids, NAVTRAEQUIPCEN Report IH 255, Orlando, FL: Naval Training Equipment Center, 1975.

Modrick, J. A., Kanarick, A. F., Daniels, R. W., & Gardner, J. A. AEMT: Technology Issues in Simulation for Maintenance Training. In W. J. King and J. S. Duva (Eds.) New Concepts in Maintenance Trainers and Performance Aids, NATRAEQUIPCEN Report IH 255, Orlando, FL: Naval Training Equipment Center, 1975.